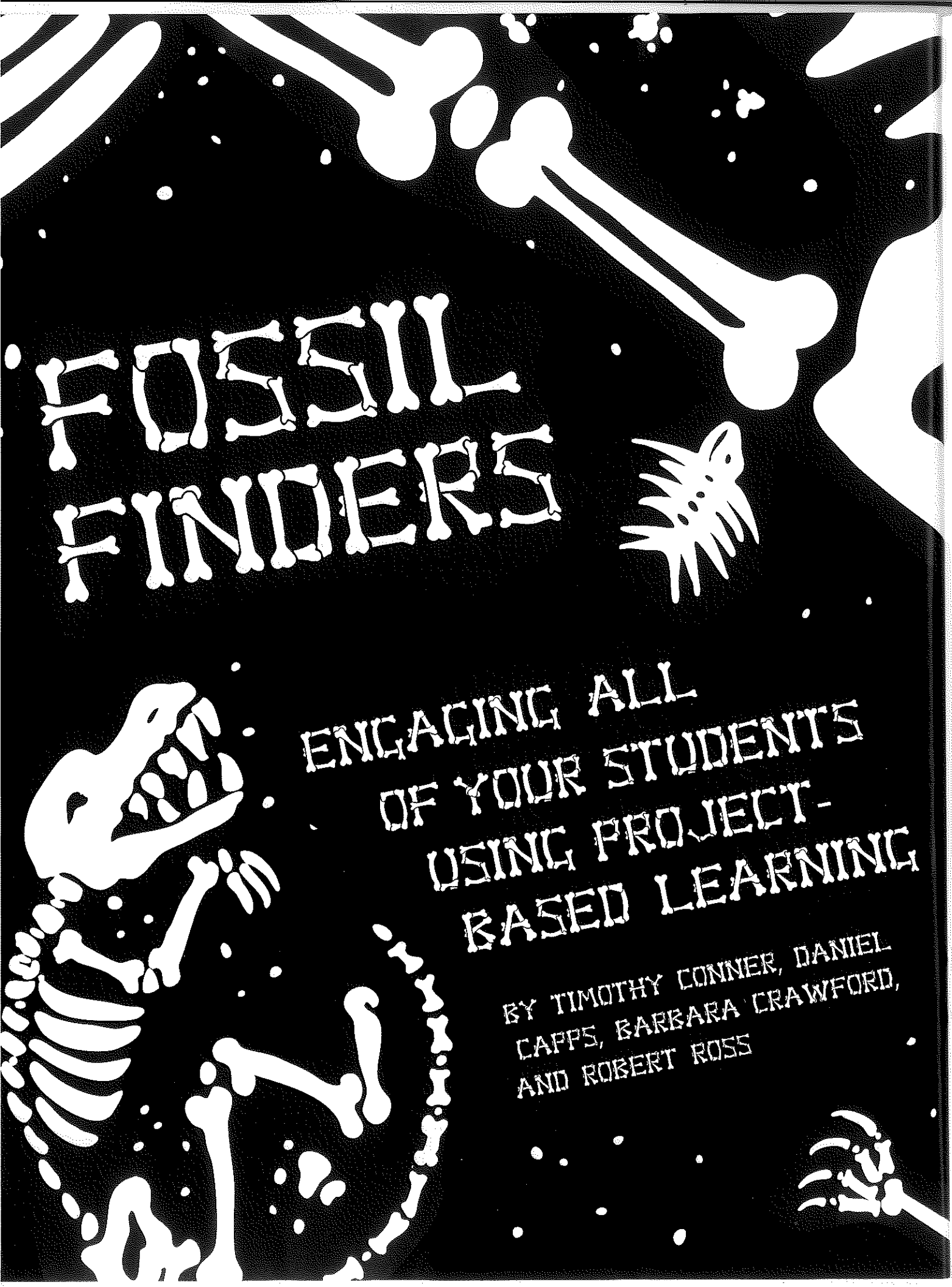


FOSSIL FINDERS

ENGAGING ALL OF YOUR STUDENTS USING PROJECT-BASED LEARNING

BY TIMOTHY CONNER, DANIEL CAPPS, BARBARA CRAWFORD, AND ROBERT ROSS

Carly, a student in my (the first author's) ninth-grade Earth science class, had behavioral problems, both in my class and in others, too. I noticed early on, however, that Carly was less disruptive on days when we did activities in class, and when we started a project called Fossil Finders, she was completely engaged. Through this project-based learning experience, Carly became an interested student and ardent paleontologist, and the two of us started a truce that lasted the rest of the year. This transformation from challenging to interested student is not uncommon when students are engaged in project-based learning; in my experience, project-based learning motivates students because it makes learning more relevant to their lives.

What is project-based learning?

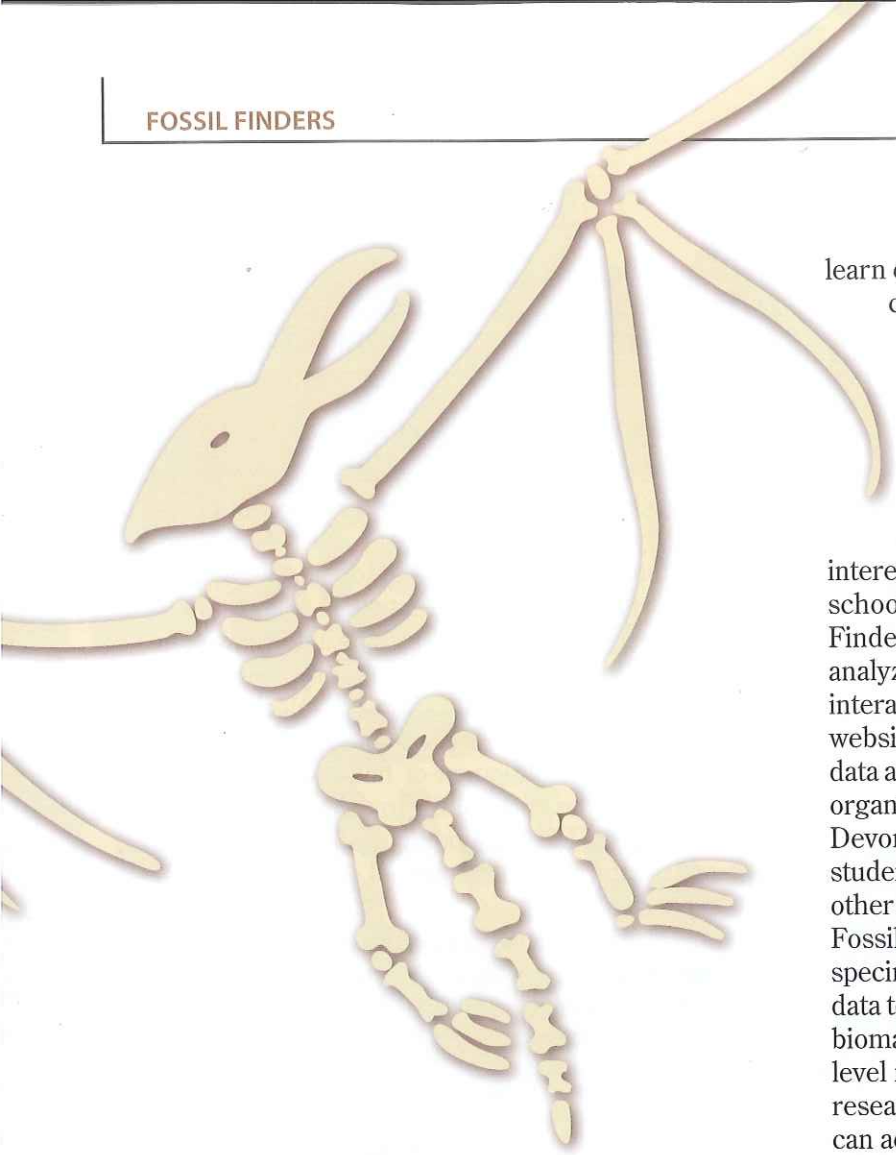
After 32 years of teaching, I am convinced that project-based learning (PBL) is one of the most effective ways to reach students. As teachers feel the increased pressure of high-stakes assessments, many dismiss PBL, because they feel that it is too time consuming and inefficient. Yet evidence exists that PBL supports academic achievement on standardized tests as well or better than traditional instruction; plus, PBL has greater potential to support the learning of higher-level cognitive skills, such as problem solving (Thomas 2000).

Good PBL happens when students are faced with an open-ended problem or challenge that is both relevant and interesting to them. Relevance and interest can be enhanced by inviting local experts to class, using places and situations that are familiar to students, or engaging them in real-word problems. Acting as a facilitator, I guide students in acquiring the skills and knowledge they need, through research and inquiry, to meet the challenge of the project. In addition to selecting a relevant problem or project, student interest is increased by adding a field component or hands-on activity, or giving students the opportunity to collect and analyze data. Cross-grade-level collaborations (e.g., high school students mentoring middle school students) further enrich a project.

I have found that in PBL, students work best in randomly assigned groups, because it breaks down the entrenched social hierarchy often present in class-

FIGURE 1 Sample PBL units

Project	Description
Woodlot Management Plan	Students work at a forested location near the school to design a woodlot management plan, which is then evaluated on-site by a state forester. After the plan is finished, students travel to a site that is being logged according to a woodlot management plan and tour the site with the forester who developed the plan. From the woodlot, students travel to a sawmill to watch lumber being produced.
Land Consulting 101	Students are challenged to act as consultants for an imaginary landowner who wants to know the value of resources on a piece of property. Students work in teams on an actual piece of property making maps, sampling, measuring, testing, and working with experts such as foresters, soil scientists, and seismologists. In the end, students prepare a professional consultant's report to submit to the landowner, including a bill for their services.
Wetland Restoration	With the help of experts from the National Aquarium's Wetland Nursery Program, students create a native wetland plant nursery (see *www.aqua.org/care/conservation-initiatives/wetland-nursery-program* for more details). After establishing a wildlife habitat area by removing invasive species from both the water and shore, students plant native nursery specimens in the local wetland. Students then assay the wetland's water quality using data obtained from probes and macroinvertebrates collected from the wetland. Students generate reports that become part of a longitudinal, student-developed study.



rooms, and new collaborations flourish. Students must draw on the strengths of their team, and any learning style and personality can be accommodated. To assign groups, I have students draw names out of a hat. See Figure 1 for examples of PBL units I have done with students in the past.

PBL and Fossil Finders

One effective PBL unit I have taught is Fossil Finders, an authentic, inquiry-based investigation of Devonian-age fossils that engages students in active research. The project was developed as a collaboration between Cornell University's Department of Education and the Paleontological Research Institution (PRI) in Ithaca, New York, and now resides at the University of Georgia, where a team of educators in the College of Education is currently enhancing the curriculum. The curriculum materials (lessons and investigation) align well with teaching students about the scientific practices described in the new *Framework for K–12 Science Education* (NRC 2012). Further, students learn core and foundational evolutionary and geological concepts. Fossil Finders lessons can be accessed for free at *www.fossilfinders.org*.

As part of the project, paleontologists send real fossil samples to schools. With the support of their teachers, students measure and identify organisms in the rocks and record the degree of fragmentation of the fossils and the rock color. Fossil samples will be available to all interested teachers for a small fee during the 2013–14 school year. For more information, visit the Fossil Finders website (*www.fossilfinders.org*). Classrooms analyzing the authentic samples enter the data in an interactive online database connected to the project's website. After the data are entered, classes can use the data as evidence to make inferences about how marine organisms responded to environmental changes in the Devonian sea. In addition to their own classroom data, students have access to data collected by scientists and other students from across the country. At present, the Fossil Finders online database has over 12,700 student specimen entries. Scientists at PRI are using the fossil data to understand, at high resolution, how faunas and biomass change as the environment changes with sea-level rise. The samples themselves are curated in the research collections at the PRI, where paleontologists can access them for perpetuity. Even if a teacher does not have the resources to purchase these actual fossil samples, they can easily access all Fossil Finders lessons and the database for free through the website. Using the database, all teachers can engage their students in asking authentic questions of data collected by other classrooms and scientists. Students can then interpret the data, build models of past environments, and create arguments using evidence.

Teaching Fossil Finders

I use Fossil Finders in a cross-grade format with my sixth-grade general science classes; my eighth- and ninth-grade Earth science classes; and my upper-level high school geology students. The unit can also be easily implemented in a single-grade classroom. Materials and resources on the Fossil Finders website are flexible, and teachers can easily adapt them to accommodate their students.

To set the stage for the investigation, I tell students that they will be doing authentic research with a university and a science museum. Their job is to carefully collect data and upload it the Fossil Finders website,

where it will be shared with students and scientists from across the country and used as forensic evidence to solve an ancient mystery: How did the organisms in the shallow Devonian sea that once existed (some 400 million years ago) change in response to environmental changes? I also tell my middle school students and high school students that at the conclusion of their investigation, they will present their findings to their classmates, to a younger grade (high school students present to eighth- and ninth-students, who present to the sixth-grade classes), and to a professional paleontologist. Students know their work has to be carefully and accurately completed, since other students and scientists are counting on them. In fact, the PRI is using the data for reconnaissance work and to compare student data to expert data with the goal of using student data in the future to test ideas needing specific data sets. Because others are actually using their data, students feel important and interested, have a lot of questions, and are eager to learn about scientific concepts, many of which (uniformitarianism, superposition, rocks, fossils, paleoecology, and inquiry skills) will appear on high-stakes tests at the end of the year. To add to the excitement of the project, I send home letters explaining to parents that their children will be engaged in authentic scientific research with a university and museum, which engages them in the project, as well.

When I teach Fossil Finders, I begin by taking my junior and senior high school geology students on a two-day field trip. They learn about the geology of the area, visit the Fossil Finders research site, which is an hour from our school, and help one of the Fossil Finders scientists collect the samples for our school. (Although most classes will not be able to visit the actual Fossil Finders site, the website has information—including links to virtual field experiences—that can help familiarize teachers and students with the geology. Further, all schools can access the data and ask their own questions of previously collected data.) When we return to the classroom, the high school geology students work in groups to practice finding and identifying fossils and using the database.

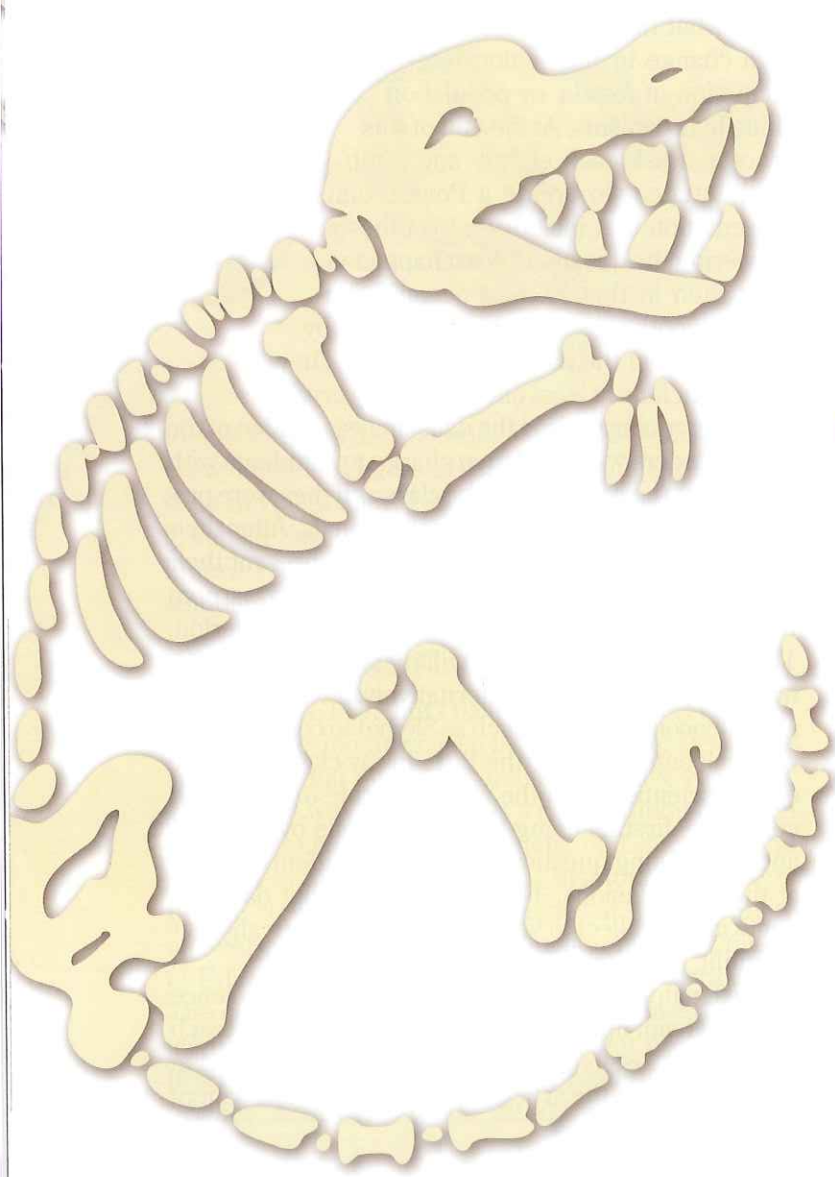
These upper-level students then teach my eighth- and ninth-grade Earth-science classes about data collection and uploading data to the website. After the eighth and ninth graders complete their data collection and upload the data, selected high school students support them in their groups as they sort and graph the data on the Fossil Finders website in order to see how fossil patterns have changed through geologic time. With students' interest piqued, it is easy to teach them what might be indicated by a change in rock color, fragmentation of fossils, or population shifts in organisms. At the end of this process, I ask each eighth- and ninth-grade student to create a PowerPoint presentation that includes a hypothesis answering the question "What happened back then in that ancient ocean?" Students' hypotheses must be supported by evidence from the data they collected. They need to include at least one graph they create using the graphing tools in the data-analysis section of the Fossil Finders website. I then charge my students with presenting their findings to the class as if they were professionals reporting to other professionals. After their presentations, students can volunteer to present their findings to a paleontologist I invite to the classroom who happens to be an expert on the Devonian period. This can be done locally if a willing paleontologist can travel to the classroom. Alternatively, a teacher could use videoconferencing (such as Skype) to communicate with paleontologists at the PRI . In my classroom, the expert scientist plays the authentic role of interested colleague, first listening to presentations by students and then asking questions about how students arrived at their conclusions. The expert asks what data students might collect to verify an idea or answer another scientific question that has arisen.

Next, pairs of eighth- and ninth-grade Earth science students team up with pairs of sixth graders and teach them about fossils (Carly, the student I mentioned at the beginning of the article, was one of the most patient

and popular teachers of the sixth-grade students). The following day, the eighth and ninth graders present their hypotheses to classes of sixth-grade students. Finally, some of the middle school students are invited to be team leaders for small groups of sixth graders on a field trip to PRI. These are supplemental activities I do in my classroom, but they are not necessary for successful PBL.

Evidence of success

This project-based learning experience engages students like Carly who typically struggle in school, while providing benefits for other students, as well (Barron and Darling-Hammond 2008). For example, Michelle, an accelerated eighth grader, was well known around school for being the perfect student, yet she was so shy she could barely ask a question in class. As expected, her work on Fossil Finders was exemplary, but I was surprised to learn that, like Carly, she was a natural and warm teacher of the sixth graders. The biggest surprise came during Michelle's PowerPoint presentation at the end of the project. Obviously distressed and nervous, she delivered a solid presentation and asked to present to the professional paleontologist. Michelle and Carly are both examples of how PBL is effective in engaging students and giving them the confidence and ability to think on their feet that few other approaches can match (Barron and Darling-Hammond 2008).



Assessment

Students were assessed both throughout the project (formative assessment) and at the end of the project (summative assessment). The formative assessment consisted of observing students' participation in group work throughout the data-collection process and checking for the completion of data sheets that are provided on the Fossil Finders website. I scored their performance on the final PowerPoint presentation using the rubric in Figure 2; some of the criteria are from the new *Framework for K–12 Science Education* (NRC 2012).

Reflection

There is no single way to teach a PBL unit, and good PBL should be flexible and adaptable. For example, my teaching of Fossil Finders is different from the way many of my colleagues from across the country teach it. The Fossil Finders website provides resources for teachers as a starting point to develop their own investigations. Using the resources as a template, teachers can adapt the lessons and investigation to fit the needs of their classroom. Like most good PBL experiences, Fossil Finders provides teachers with a framework within which they can weave fieldwork (virtual or actual), hands-on activities, and data collection and analysis into a rigorous experience for students. In the end, students have a rich experience working on authentic research while getting help from professional paleontologists. A well-designed PBL unit, like Fossil Finders, is real and relevant and motivates students to learn difficult material (Thomas 2000). ■

FIGURE 2 Rubric used to assess students' final presentations

Criteria	Points
Poise and professionalism during the presentation • Student speaks audibly and clearly (5 points). • Student uses appropriate language (5 points).	10
Quality of PowerPoint presentation • The presentation is well constructed (5 points). • The presentation highlights the major points made by the speaker (5 points).	10
Asking questions and defining problems (NRC 2012) • Student states problem or question being investigated (10 points). • Student justifies why the question or problem is interesting/important (10 points).	20
Planning and carrying out the investigation (NRC 2012) • Student describes what data are to be gathered (10 points). • Student describes how data will be gathered (10 points).	20
Analyzing and interpreting data (NRC 2012) • Student constructs appropriate graphs and tables (10 points). • Student analyzes data looking for patterns to answer the original question (10 points).	20
Constructing explanations (NRC 2012) • Student offers explanations based on analysis of data (10 points). • Student identifies weaknesses in explanation (10 points).	20
Total	100

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